Sedimentary Geology 308 (2014) 53–62

Contents lists available at ScienceDirect

Sedimentary Geology

journal homepage: www.elsevier.com/locate/sedgeo

Distinguishing different sedimentary facies in a deltaic system

Barendra Purkait [a,*], Dipanjan Das Majumdar [b]

[a] Department of Geology, University of Calcutta, 35, Ballygunge Circular Road, Kolkata 700035, India
[b] Department of Remote Sensing & GIS, Vidyasagar University, Midnapur, West Bengal 721102, India

ARTICLE INFO

Article history:
Received 28 February 2014
Received in revised form 13 May 2014
Accepted 14 May 2014
Available online 22 May 2014

Editor: J. Knight

Keywords:
Sedimentary facies
Grain-size distribution
Log-normal
Log-skew-Laplace
Discriminant functions

ABSTRACT

An attempt has been made to differentiate sedimentary facies in a modern deltaic system by means of grain-size characteristics of the Ganga alluvial plain of West Bengal, India. Three main energy environments (marine, mixed and riverine) comprising the delta were considered. Sand samples were collected from rivers (both tidal and non-tidal), coastal dunes, beaches and tidal flats of the deltaic plain. The grain-size distribution patterns were compared with the two model distributions of log-normal and log-skew-Laplace. Different sedimentary facies were identified by discriminant functions. The analytical results indicate that the energy gradient of the different sedimentary facies of the deltaic system is well reflected by the grain-size characteristics of the individual facies. While critically analyzing the role of different textural parameters in discriminating the individual facies associations, it is observed that the mean size, alpha (slope of coarser fractions of Laplace model) and skewness have greater potential to distinguish different sedimentary facies of the deltaic system. The results of discriminant analysis might be applicable to paleo-environmental interpretation of a deltaic system by distinguishing the individual facies associations.

1. Introduction

River deltas, the most significant coastal morphological and depositional features, are sites of freshwater input into the sea and often cause prominent stratification in coastal waters, leading to stagnant bottom conditions and the accumulation and preservation of organic matter within thick sedimentary sequences. Deltas are among the most important sedimentary deposits because they record changes across marine and terrestrial environments (Edmonds et al., 2011). Heterogeneous energy fields under different hydraulic processes (river, tide and wave) produce different landforms with different particle-size characteristics. Many landforms, such as distributary channels, mouth bars, sand sheets, distal bars and tidal flats are very important reservoirs in oil and gas fields. Therefore, deltas are favorable sedimentary settings for oil accumulation because the interbedded reservoirs there are closer to the potential source rock. Consequently, there is an urgent need to understand the sedimentary processes and the identification of different sedimentary sub-environments of a deltaic system.

A large amount of research has been carried out on the grain-size characteristics of different sedimentary environments (e.g., Mason and Folk, 1958; Friedman, 1961, 1967, 1979; Shepard and Young, 1961; Folk, 1966, 1968; Hails and Hoyt, 1969; Purkait, 1972, 1991; Stapor and Tanner, 1975; Taira and Scholle, 1979; Sahu, 1983). Passega (1957, 1964) presumed that the particular CM (C = one percentile and M = mean size) pattern is indicative of the depositional agent or process. Sahu (1964), Moiola and Spencer (1979) and Kasper-Zubillaga and Carranza-Edwards (2005) used discriminant analysis and Klovan (1966) used factor analysis to describe variability among observed correlated variables, in terms of a potentially lower number of unobserved variable (factor), to differentiate depositional sedimentary environments. As each environment is related to a particular hydrodynamic condition of deposition, neither assumption is wholly valid. The ideas of Bagnold (1937) and Krumbein (1938) highlighted the deficiency of conventional grain-size distribution diagrams where the grain-size frequency is plotted against log particle size (i.e., phi scale, $\Phi = -\log_2 d$ where d = particle diameter in mm). It is significant that grain-size distribution patterns have a different appearance when both size and frequency are plotted on a log–log scale to differentiate different depositional environments (Bagnold and Barndorf-Nielsen, 1980; Barndorff-Nielsen et al., 1982; Fieller et al., 1984; Vincent, 1986; Fieller and Flenley, 1992; Purkait, 2000, 2002, 2003, 2006, 2010, 2011; Purkait and Mazumder, 2000).

Kasper-Zubillaga and Dickinson (2001) made an attempt to differentiate beach, dune and river environments in terms of their mineralogical components by using simple bar charts. However, textural differences of grain-size among different depositional environments with varying hydrodynamic settings like a deltaic system have not been studied in detail. In this study we have followed a systematic analysis to differentiate the different depositional sedimentary environments of the Sunderban deltaic system (Fig. 1) from the analysis of a) textural parameters of sands and b) grain-size distribution patterns. A three-tier methodology has been adopted for this research. In the first

* Corresponding author.
E-mail addresses: baren_purkait@yahoo.co.in, baren.purkait@gmail.com (B. Purkait), dipddm@gmail.com (D.D. Majumdar).

http://dx.doi.org/10.1016/j.sedgeo.2014.05.001
0037-0738/© 2014 Published by Elsevier B.V.

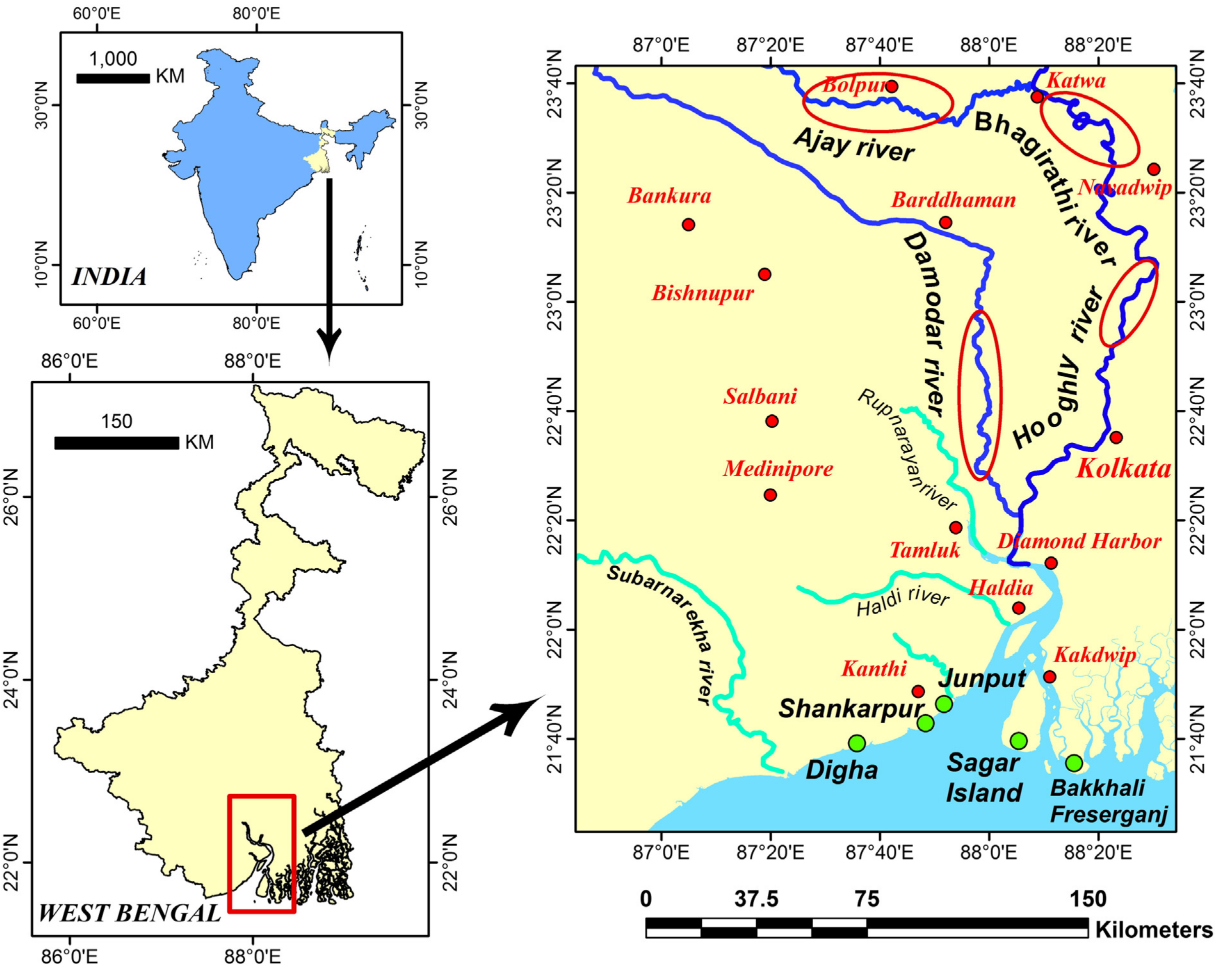

Fig. 1. Location map of the study area showing the position of different sedimentary sub-environments of the deltaic system of the Ganga River. Studied river stretches are shown in oval shape.

tier, different sub-environments or sedimentary facies were separated in the light of the best-fit statistical grain-size distribution model. In the second tier, multiple mean comparisons among the categorical variables (textural parameters) were analyzed, and in the last tier, with the help of a discriminant model, a final conclusion on distinguishing different sedimentary sub-environments in a deltaic system was reached.

2. Geomorphological set-up

A schematic diagram of the Sunderban deltaic system shows the different sub-environments under study (Fig. 2a). A total of three different sub-environments (marine, mixed and riverine) comprising the delta were considered. The different sub-environments were selected in a systematic way from the deltaic system of the Sundarban Delta. Considering the environmental gradient of the delta (Fig. 2b), the sub-environment classification was done on the basis of the dominant hydrodynamic operators in each environmental domain. A total of five sub-environments were selected: from the marine environment — beach and dune, from the mixed or transitional environment — the tidal flat, and finally from the riverine environment — both the tidal and non-tidal rivers (Fig. 2b). A description of the locations (Fig. 1) is given in the following section.

2.1. Coastal belt of Sagar Island and its adjoining coastal belts

Sagar Island, a part of the Sunderban Delta (Fig. 1) exhibits a high energy, macro-tidal coast with a tidal range larger than 4 m (Pethick, 1984; Paul, 2002; Purkait, 2008). A detailed description has been given elsewhere (Purkait, 2012). Fluvial, marine, tidal and aeolian processes are the chief agents actively shaping this coastal zone. The macrotidal environment of West Bengal shores often provides extensive areas of tidal flats. The relatively younger coastal foredunes, reaching about 1 m in height, border the beach and consist of fine sands. Older longitudinal dunes up to about 5 m high occur farther inland. The Bakkhali–Freserganj coastal belt, extending for about 2 km in a northeast–southwest direction, is situated about 30 km south-east of Sagar Island (Fig. 1) and consists of fine to medium sands with some admixtures of silt and clay. The area forms a part of the Hooghly Delta and is only a few km east of the Hooghly Estuary (Fig. 1). The major geomorphic units consist of a flat, wide foreshore, a narrow backshore with discontinuous dunes, and saline back-water marshes fed by water of the high-tide entering along small creeks. The spring tidal height is ~5.10 m. The beach is gently sloping (3–4°) with a dominance of fine sands. The dunes form ridges and individual dunes attain heights of 1–2 m. The Bakkhali dunes are prominent and numerous whereas the dunes of Freserganj are in decline as compared to the Bakkhali dunes.